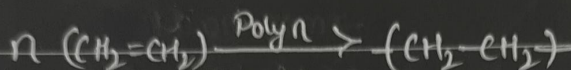


① Macromolecules \rightarrow large molecules formed by polymerization of small molecules (monomers).

Polymerization \rightarrow chem. rxn - small molecules (monomers) combine to form larger molecule (polymer). with/without elimination of small molecules like H_2O , HCl , etc.



α = $\frac{\text{mol. wt of Polymeric network}}{\text{mol. wt of Repeating unit}}$

Functionality \rightarrow No. of bonding site / functional grp present in monomer.

\rightarrow Bifunctional - 2

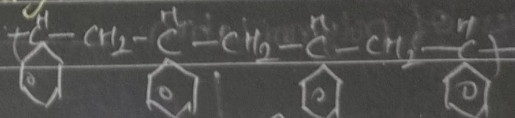
\rightarrow Trifunctional - 3

\rightarrow polyfunctional - > 3

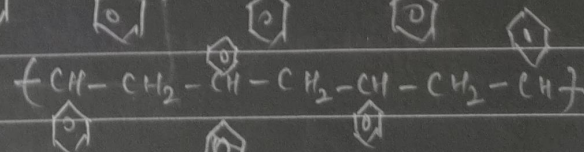
	$f(x)$
$CH_2=CH_2$ (2 sides on both sides)	2
CH_3COOH (COOH)	1
$H_2N(CH_2)_6NH_2$ (NH ₂)	2
CH_2OH (OH)	3

Tacticity \rightarrow orientation of monomeric / functional unit in a polymer can take place in orderly / disorderly manner w.r.t main chain is called tacticity.

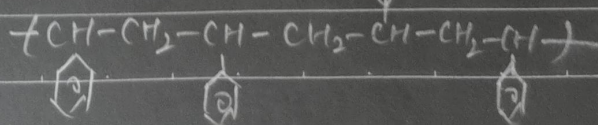
\rightarrow Isotactic - same side



\rightarrow Syndiotactic - alternating side



\rightarrow Atactic - randomly



② Classification :

1) Based on Origin

Natural polymer

- plants & animals
- protein, starch, cellulose, etc

Semi Synthetic

- derived from natural polymer w. modification.
- PVC, Nylon

Synthetic

- man-made
- plastic, synthetic rubber.

2) Based on Nomenclature :

Homo polymer

Same type of monomer

* Linear $-M-M-M-$

* Branched $-M-\underset{\substack{| \\ M}}{M}-M-$

* Cross-linked $\begin{array}{c} (M-M-M) \\ | \\ M-M-M-M-M \\ | \\ M-M-M-M-M \end{array}$

Hetero polymer

more than 1 type

* Random $-M_1-M_2-M_2-M_1-$
 $-M_1-M_2-$

* Block $-M_1M_1M_2M_2M_1M_2M_2-$

* Graft $-M_1-M_1-M_1-M_1-$
 $\begin{array}{c} M_2 \\ | \\ M_2 \\ | \\ M_2 \end{array}$

(M_1 → main chain)

Homochain poly

main chain made up of same species

$-C-C-C-$

Heterochain poly.

main chain made up of different species.

$-C-O-C-O-$
 $\begin{array}{c} C \\ | \\ O \\ | \\ C \end{array}$

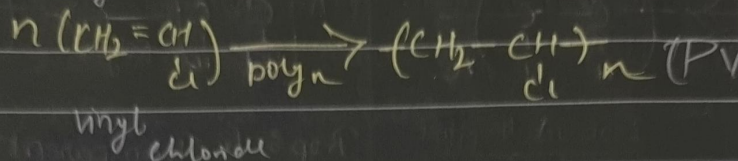
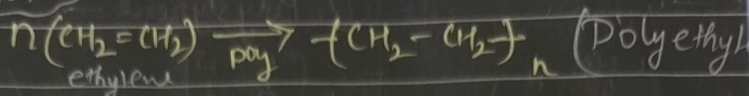
③ Types of polymerization

→ Addition [thermo plastic]

→ Condensation [thermosetting]

* Addition: \rightarrow chem. rxn that yields exact copy of itself

forms thermoplastic \rightarrow no elimination of molecule (small)



Condensation: \rightarrow chem. rxn that yields completely diff from the original compound.

forms thermosetting

\rightarrow elimination of molecule (small)

Example: Nylon 6,6, PET, Polyurethane [Explained in next coming page].

*

Thermoplastic

\Rightarrow Prep. by Addition

\Rightarrow Linear polymer

\Rightarrow Can be moulded into any shape
(heating - soft, cooled - hard)

\Rightarrow Weak intermolecular force of attraction & weak covalent bond.

\Rightarrow Soluble in organic solvents.

\Rightarrow Eg: polyethylene, PVC.

Thermosetting

\Rightarrow Prep. by Condensation

\Rightarrow Cross-linked Polymer.

\Rightarrow Can't be moulded easily. But they can be set to any shape quickly.
(on heating - hard; once hard cooling not possible)

\Rightarrow Strong intermolecular force of attraction and strong covalent bond.

\Rightarrow Insoluble in organic solvents

\Rightarrow Bakelite, polyester.

Addition Homochain

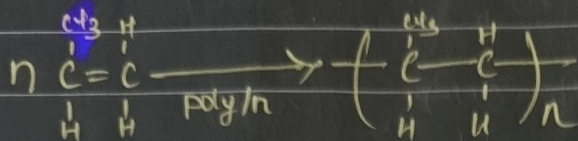
- involves only 1 monomer
- gives exact copy of itself and no loss of simple molecule.
- same empirical formula
- PVC, Teflon, polyethylene

Condensation heterochain

- > 2 monomers
- form complexly diff molecules.
- loss of simple molecule.
- diff. empirical formula
- Nylon 6,6, Bakelite.

Examples for Thermoplastic

① Polypropylene —



Prop: Isotactic.

Isotactic hospital

2. Posses hardness, strength, stiffness.

3. Stiffer, harder, stronger than polyethylene.

Uses: * Rope, carpet (indoor/outdoor)

* hand bags, blanket

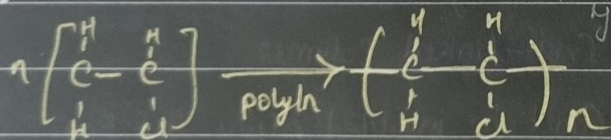
* furniture

* machine parts, water pipes

* hospital sterilizable equipment.

③ PVC —

colour odour hard Synthetic



Prop: 1. colourless, odourless

2. Pure resin posses highly softening & greater stiffness and rigidity compared to polyethylene (but brittle)

3. Widely used in synthetic plastic

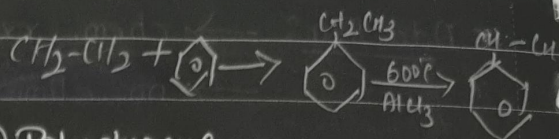
2 types $\begin{cases} \text{Rigid PVC} \\ \text{Plasticized PVC} \end{cases}$

Uses:

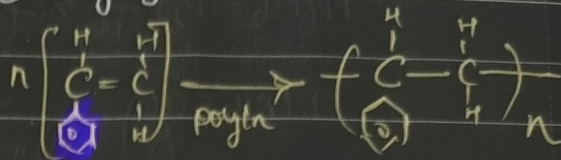
Rigid: light fittings, safety helmets, toys.

cycle & bike mudguard, refrigerator components

PVC: Ram coats, curtains, cloth, toys, tool handles, radio components



② Polystyrene —



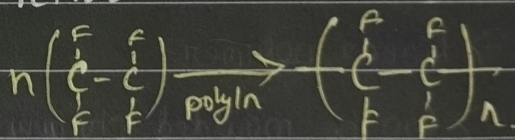
Prop: 1. Transparent translucent resistant

2. Excellent chem, electrical, moisture resistance. Also acid.

3. light, stable, unique property of transmitting light through curved section

Uses: Toys, button, radio/TV parts, refrigerator parts, lens, Indoor lighting panel

④ Teflon —



Prop: 1. Due to presence of highly electronegative fluorine atom results in strong attractive force b/w chain
That attractive force gives extreme toughness & high softening point

2. high chem resistance, high density.

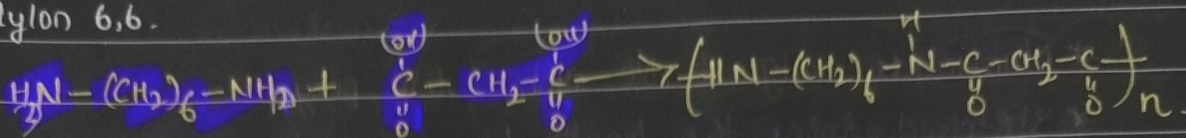
Uses: * Insulating material

fast motor, transformer, cable cones

* Gaskets, perfect material, pump parts

Examples for Thermosetting

① Nylon 6,6.



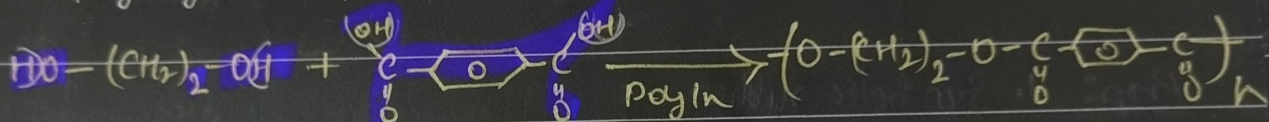
Prop:

1. translucent property.
2. abrasion resistance.
3. high temp. solubility
4. insoluble in organic solvent

Uses

⇒ used in fibres.
 ⇒ use in making of carpets, drap, curtain, etc.

② PET (poly ethylene terephthalate)



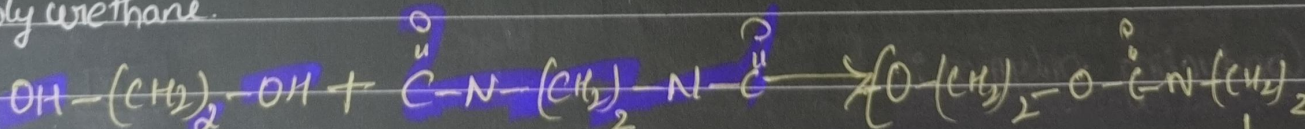
Prop:

1. highly resistant to minerals and organic acids but less resistant to alkali
2. is a good fibre forming material and used as commercial fibre.

Uses

⇒ used as synthetic fibre.
 ⇒ making safety helmets.
 ⇒ aircraft battery box

③ Polyurethane.



Prop:

1. high resistance for oxidation
2. " for organic solvents
3. " heat, abrasion & chemicals

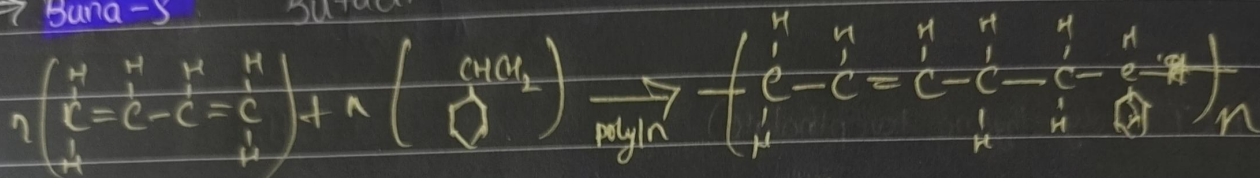
Uses:

⇒ film milk, coating, foam
 ⇒ foundation garment, swimsuit.
 ⇒ used as leather substitute.

④ Synthetic Rubber:

- * Man-made vulcanisable rubber like polymer.
- * Stretched twice the length but return to same shape as per force is left.
- * Eg: Buna-S

⇒ Buna-S Butadiene styrene



Prop: 1. Synthetic rubber.

2. Abrasion resistant & Oxidation heavy.

3. vulcanizable similar to natural rubber by sulphur.

(S \propto vulcanizable)

Uses: * manufacture of tyres.

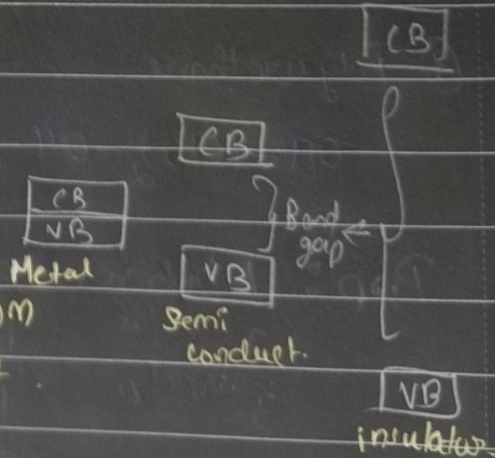
* gaskets, floor tiles & cable insulation.

Conducting polymer:

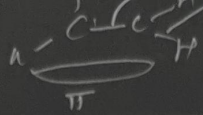
Valence Band — Outer orbit filled w. e^-

Conduction Band — region, where free space for e^- from valence band to jump in during excess energy.

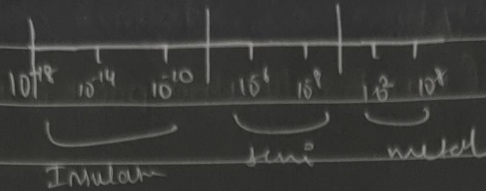
Band gap — Energy diff. b/w valence Band & Conduction Band.



Band gap \propto amt. of energy for e^- transfer



Fermi lvl - highest energy state occupied by e^- in material



Requirements for conducting polymer:

⇒ linear backbone

⇒ alternate double bond



⇒ due to either πe^- or doped ingredient.

Characteristics:

- Conduct electricity coz of π bond.
- either metallic / semiconductor.
- high electric conduction
- In pure form low electric conductance (act like insulator)
- Processibility by dispersion.

Conducting Polymer

Intrinsically conducting

π bond, extension of e^-

Extrinsically conducting

filled polymer

Bulk.

Conducting polymer having conjugate electric conduction due to π & double bond.

Doped

conducting polymer

→ adding substance inside polymer

→ involves partial oxidation/reduction of π bond of polymer

→ substance either +ve/-ve.

p type

n type.

oxidizing agents

• create +ve charge on polymer

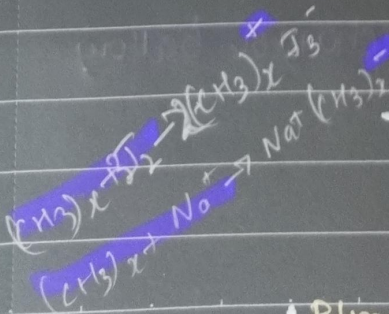
• P type = Polymer + Lewis acid (F_2, Cl_2)

reducing agents

• create -ve charge on polymer

• Polymer + Lewis Base (Na^+, K^+) = n type.

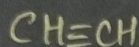
Dopants are chemical substance used to test electrical conductance by doping.



Factors affecting conductivity:

- 1) Conjugation length \propto conductivity \uparrow
- 2) Doping level \propto conductivity (until saturation point is reached)
- 3) Temp \propto conductivity \uparrow

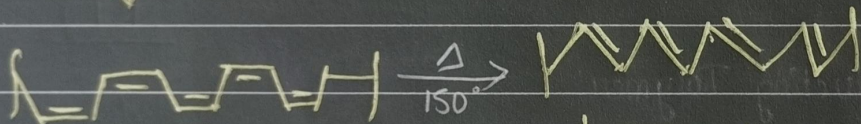
1) Poly acetylene $(C_2H_2)_n$



Ziegler Natta (Catalyst)

$-78^\circ C$

$150^\circ C$



cis polymer

\Rightarrow same side

\Rightarrow Copper coloured

trans-polyacetylene

\Rightarrow alternating

\Rightarrow Silver coloured.

\Rightarrow Flexible & stretched.

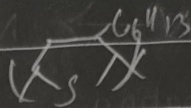
\Rightarrow brittle

* Both highly thermal stable

* Insoluble in organic solvent (Both)

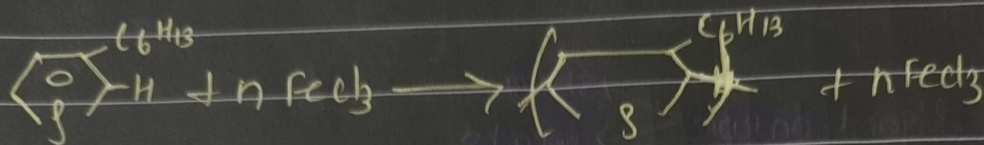
Uses: high conductivity - used in wiring & rechargeable battery
sensor to measure glucose conc.

2) P3HT [poly(3-hexyl thiophene)]:



widely available, low cost, easy processability

Semi-crystalline polymer.



⇒ 1:4 ratio, oxidation of 3-hexylthiophene monomers.

- ① Rxn flask - Anhydrous FeCl_3 w/ chloroform & N and sealed
- ② using syringe 3-hexylthiophene added slowly.
- ③ Covered out room temp; cooled w/ methanol.

Prop: * wide availability

* low cost & easy processability

* P-type donor.

* In order to ↑ absorption of excess solar radiation

1. Compare HOMO-LUMO

2. ↓ LUMO

3. ↑ HOMO.

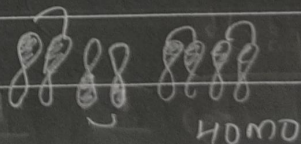
Uses: used as solar cell

" polymer batteries.

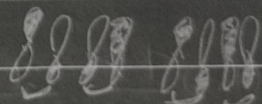
" treatment in skin disease.

" organic photovoltaic

HOMO → highest occupied energy molecular orbital
LUMO → lowest unoccupied next highest energy orbital that is empty.



HOMO



LUMO

LUMO energy > HOMO